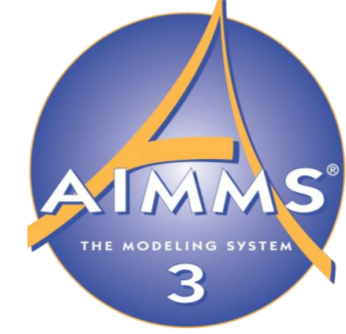


RESEARCH AREA

- Medium scale distributed gen. connected to medium voltage
- Non-firm generation -> curtailment
- Planning and operation stage
- Distributed wind generation reactive power (Q) resource

MATHEMATICAL MODEL



- AC Optimal Power Flow (AC OPF) model (Nonlinear Programming)
- Planning/operation AC OPF model in AIMMS optimization software
- Planning stage: maximise generation at minimum demand
 - Fixed power factor limits (0.96 ind., 0.98 cap.)
- Operation stage: Generation/demand time series
 - AC OPF ran consecutively for each time step
 - Max. energy export: min. loss, max. wind power output
 - Piecewise linear Q capability, P and Q largely decoupled

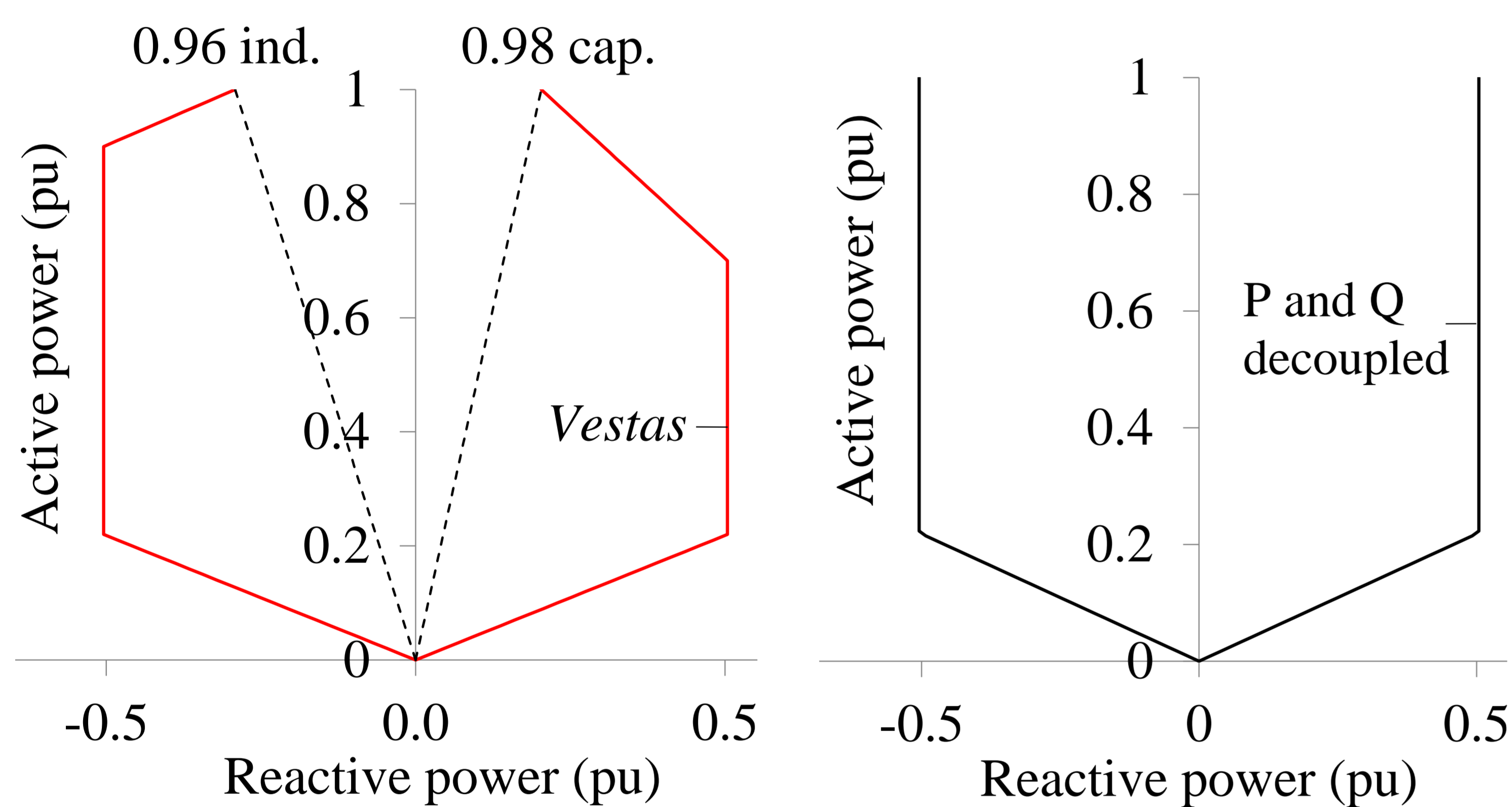


Fig. 1 Asymmetrical (source: Vestas) and symmetrical Q capability diagram

AC OPF PLANNING STAGE

- 6 bus 38kV distribution network (source: ESB Networks, 2010)
- $V_{nom}=38$ kV, $V_{max}=42.5$ kV, $V_{min}=36.5$ kV, $V_1=41.6$ kV
- Firm (nominal V and I limits): 42.6 MW
- Non-firm (V_{max} and I \uparrow 10%): 70.1 MW (\uparrow 64%)

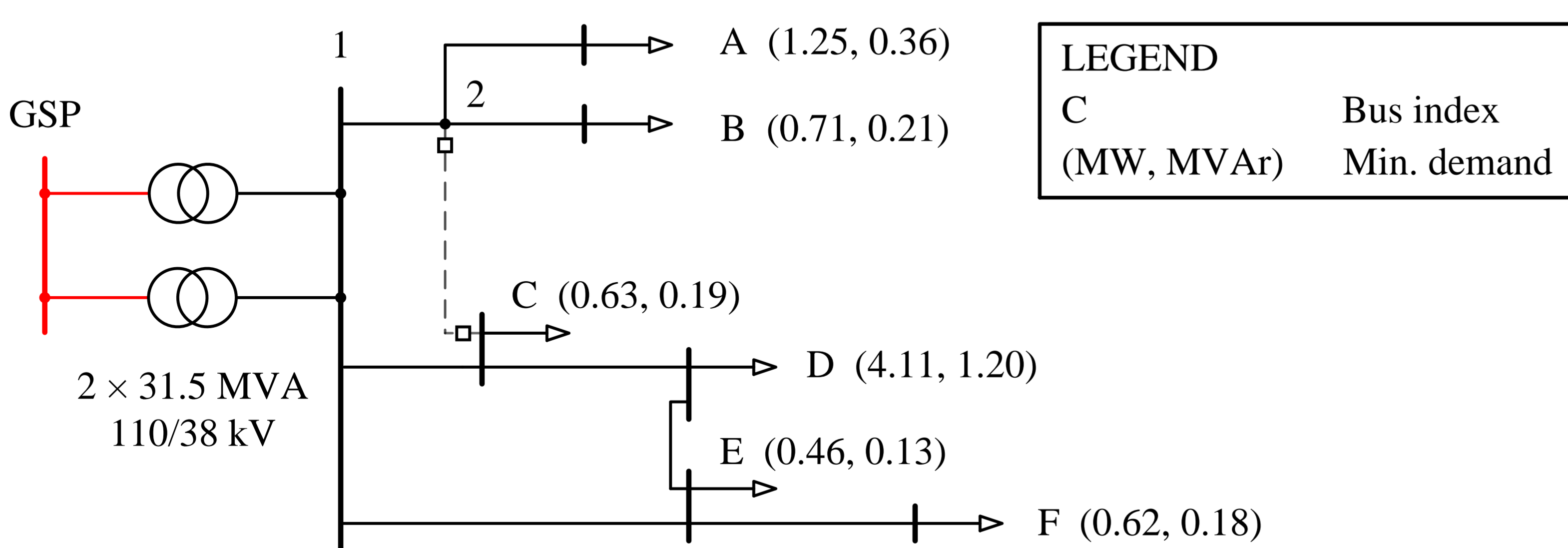


Fig. 2 Representative Irish distribution network at minimum demand

ACKNOWLEDGEMENT

This work was conducted in the Electricity Research Centre, University College Dublin, Ireland, which is supported by Bord Gáis Energy, Bord na Móna Energy, the Commission for Energy Regulation, Cylon Controls, EirGrid, Electric Ireland, the Electric Power Research Institute (EPRI) (US), Energia, ESB International, ESB Networks, Gaelectric, Intel, SSE Renewables, and United Technologies Research Centre, Ireland (UTRCI).

Mario Džamarija and Andrew Keane are supported by Science Foundation Ireland under Grant Number SFI/06/CP/E005.

AC OPF OPERATION STAGE

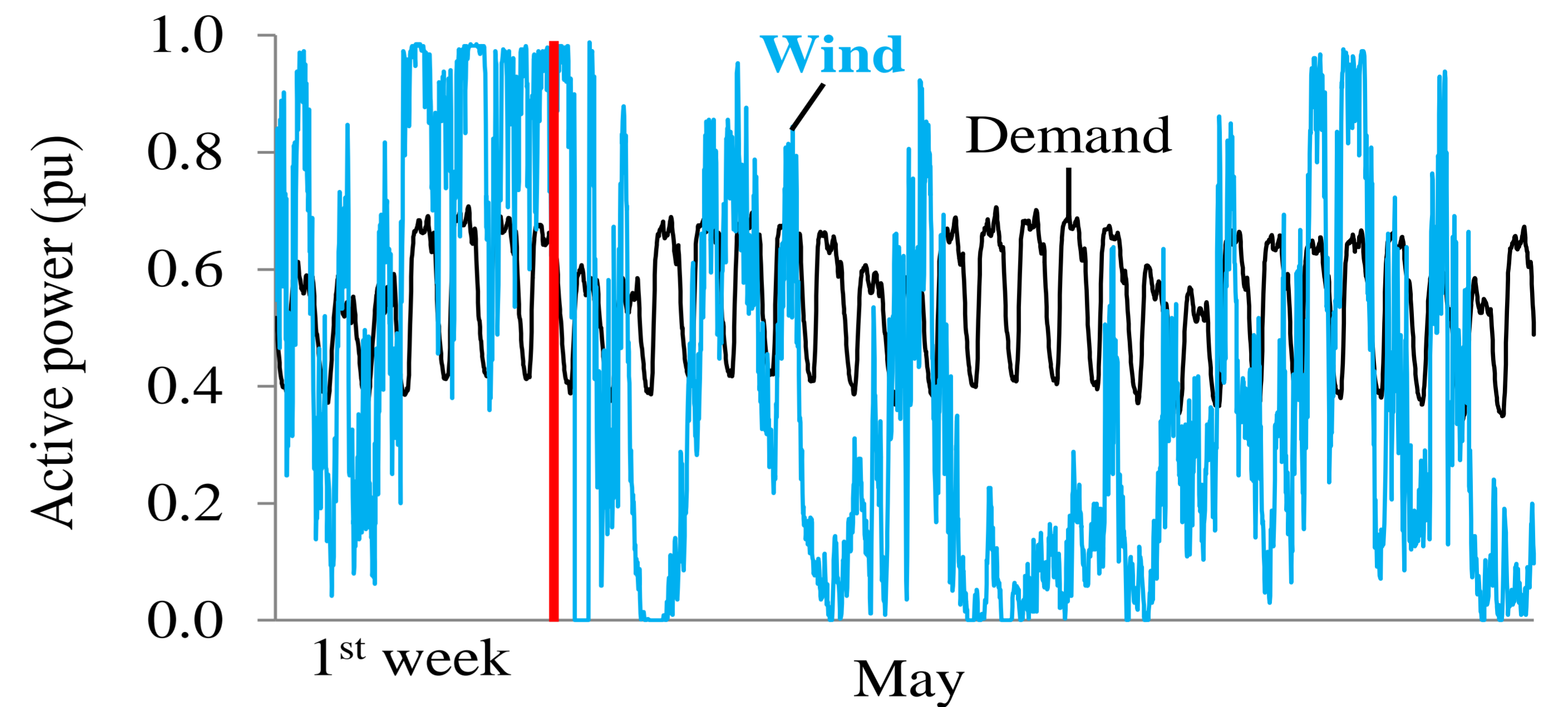


Fig. 3 Quarter hour wind power and demand, relative to peak values, 2010

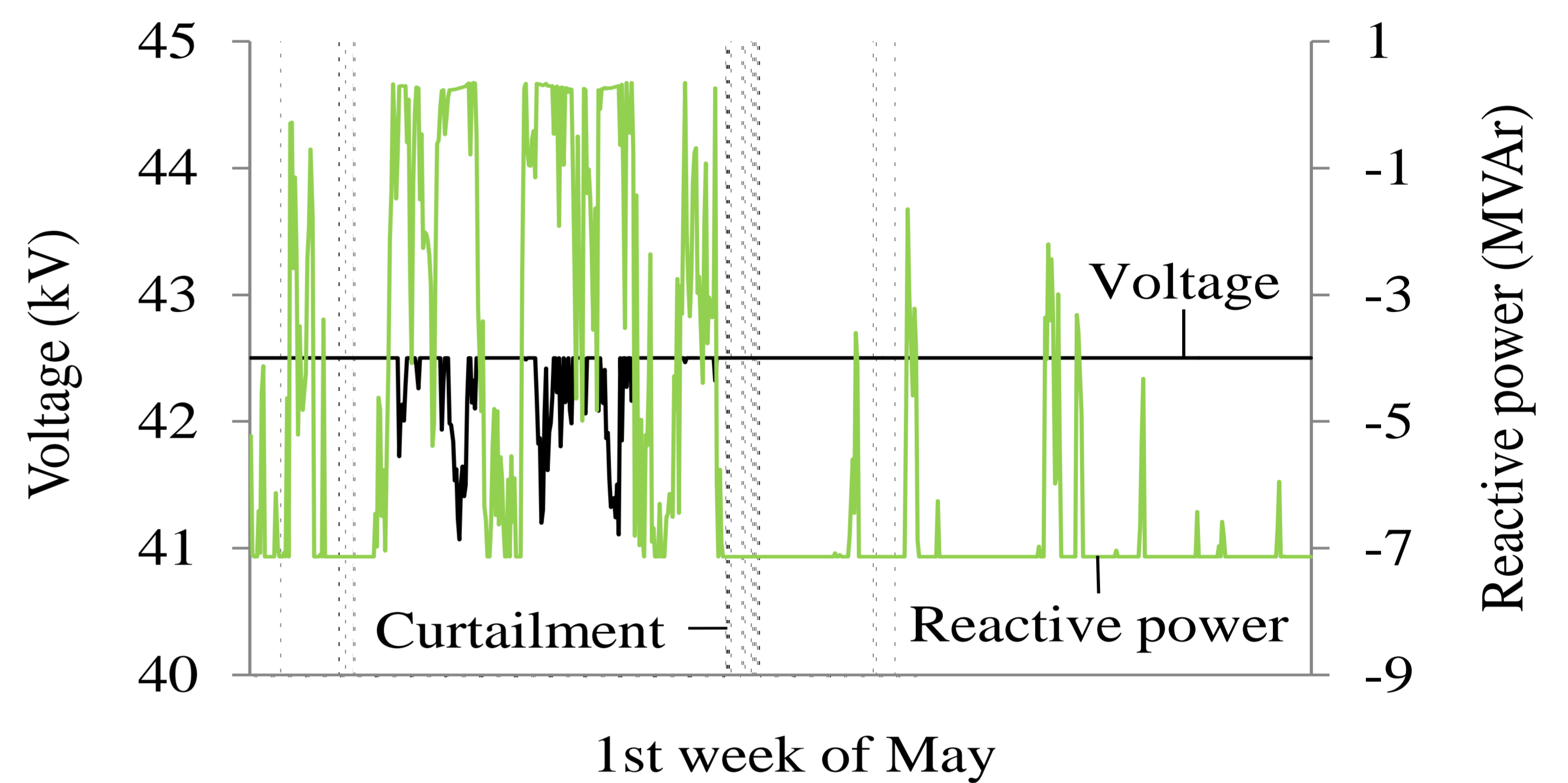


Fig. 4 Wind power curtailment without current constraint: Q-V interrelation diagram in respect of time for wind farm (WF) F connected to bus F

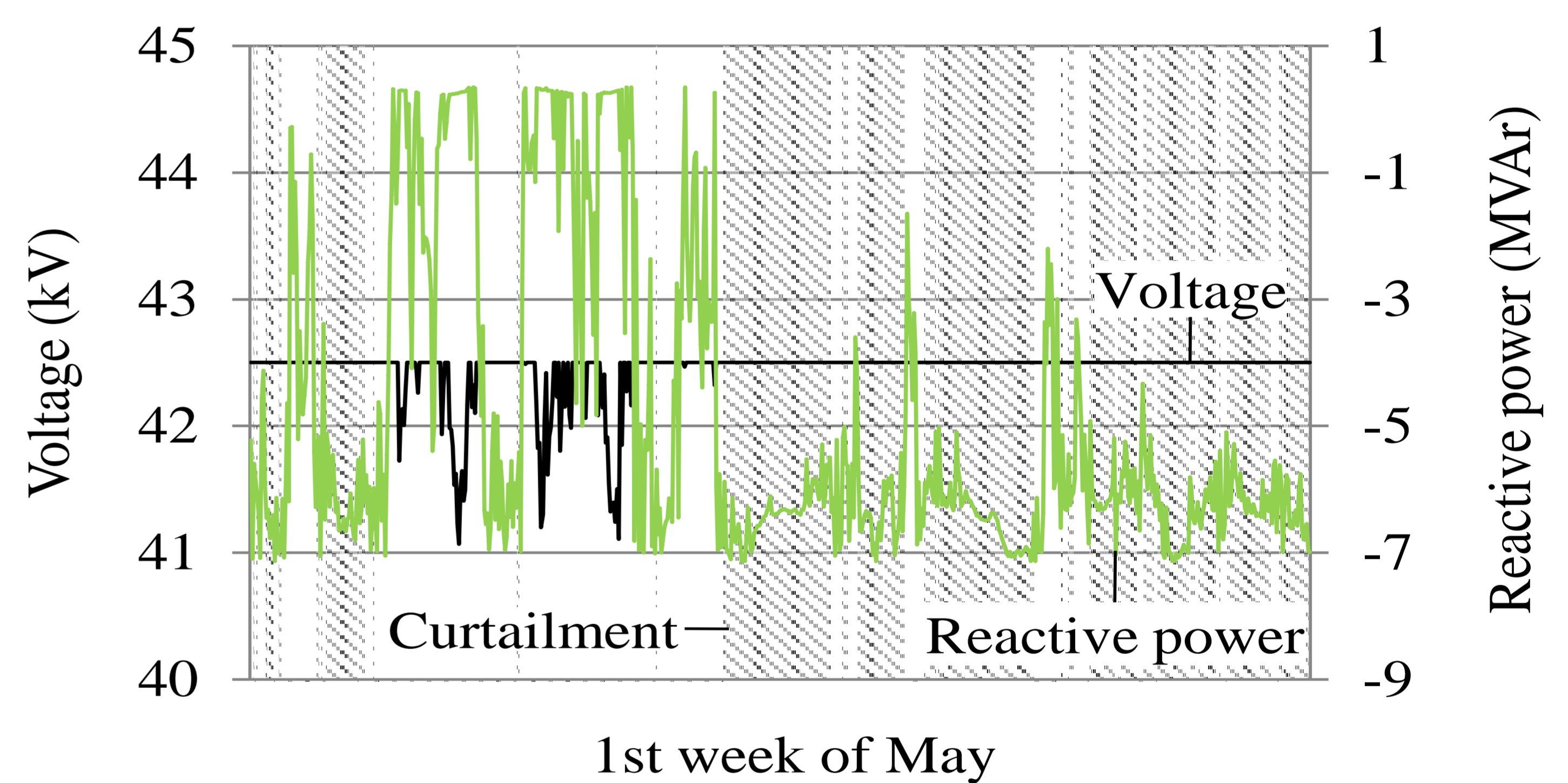


Fig. 5 Wind power curtailment with all constraints: Q-V interrelation diagram for WF F connected to bus F

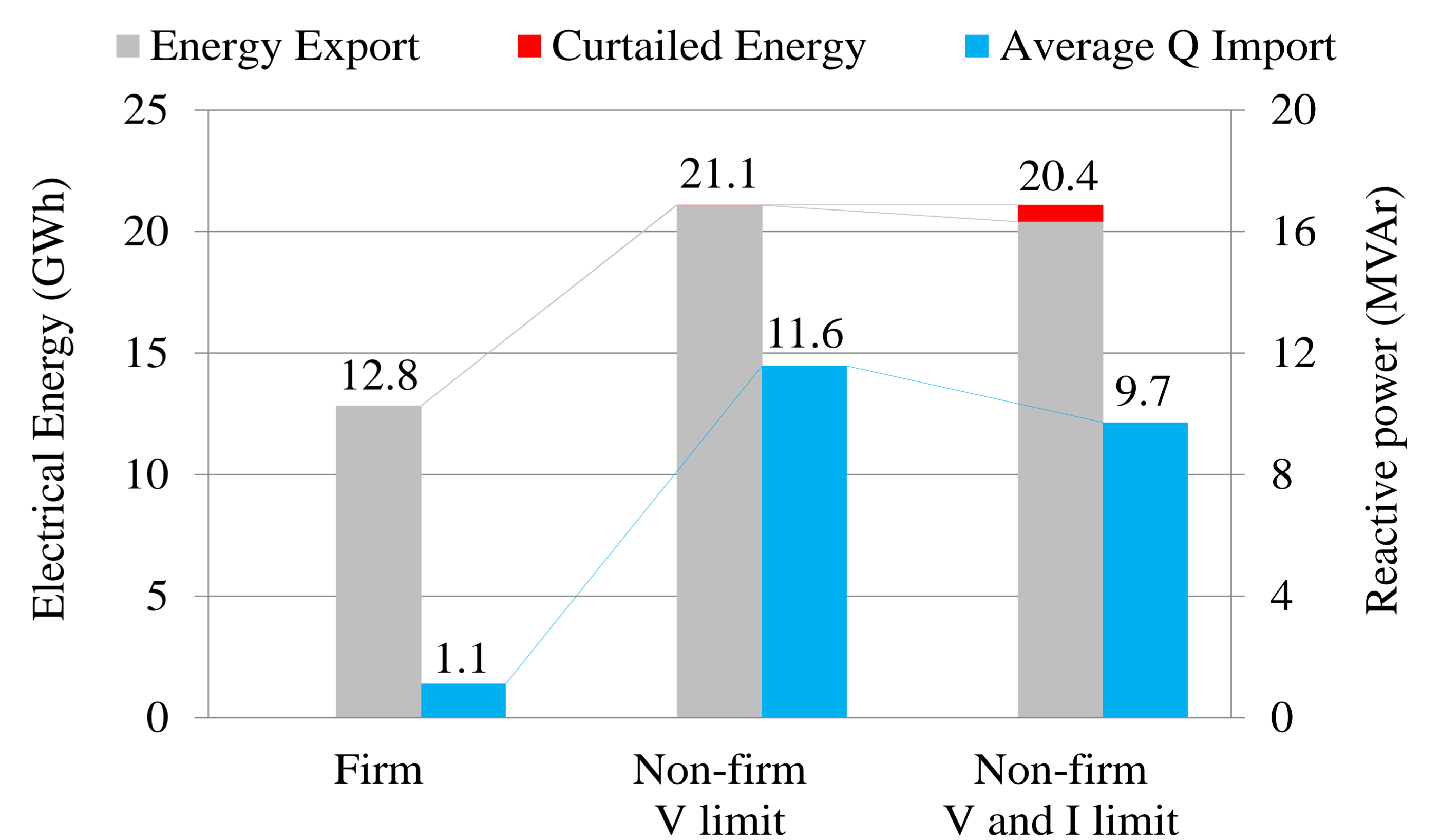


Fig. 6 Firm and non-firm operation stage results summary

CONCLUSIONS

- 59% increase in energy harvesting, 96.7% wind energy utilized
- WFs are required to absorb Q in order to deal with V rise
- SIDE-EFFECT:** binding V_{max} and I constraint hinders WFs from using full Q capability